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**Sibbach et al.**

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(54) **ICE REDUCTION MECHANISM FOR TURBOFAN ENGINE**


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(51) **Int. Cl.**

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| ***F02K 3/06*** | (2006.01) |
| ***B64D 33/02*** | (2006.01) |

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(58) **Field of Classification Search**

CPC ... F02C 7/04; F02C 7/047; F02C 9/18; B64D 33/02; B64D 33/0233; B64D 2033/0233; F02K 3/06

See application file for complete search history.



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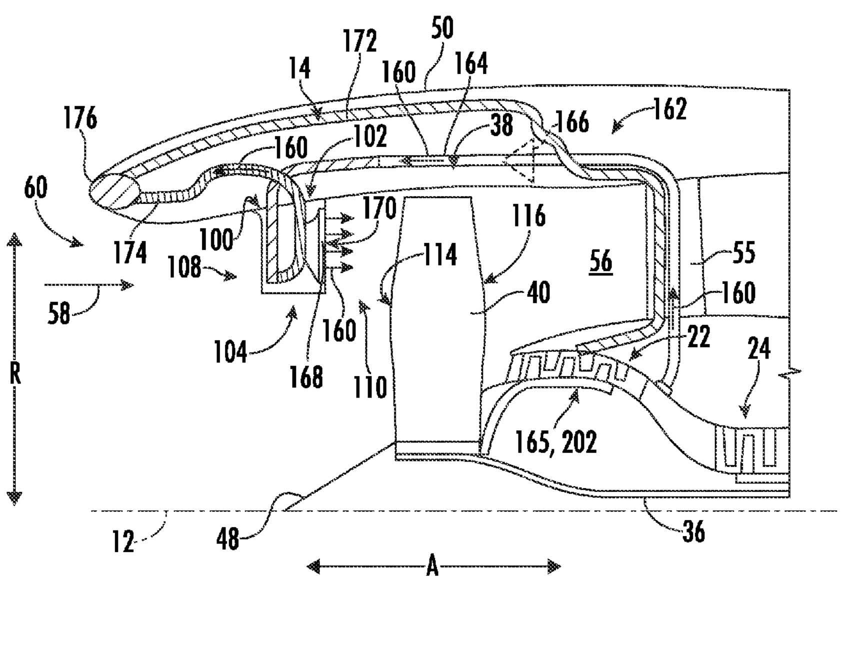
(57) **ABSTRACT**


A turbofan engine is provided. The turbofan engine includes a fan comprising a plurality of fan blades; a turbomachine operably coupled to the fan for driving the fan, the turbomachine comprising a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath; a nacelle surrounding and at least partially enclosing the fan; an inlet pre-swirl feature located upstream of the plurality of fan blades, the inlet pre-swirl feature attached to or integrated into the nacelle; and a means for reducing ice buildup or ice formation on the inlet pre-swirl feature, the means in communication with the inlet pre-swirl feature.


**6 Claims, 7 Drawing Sheets**



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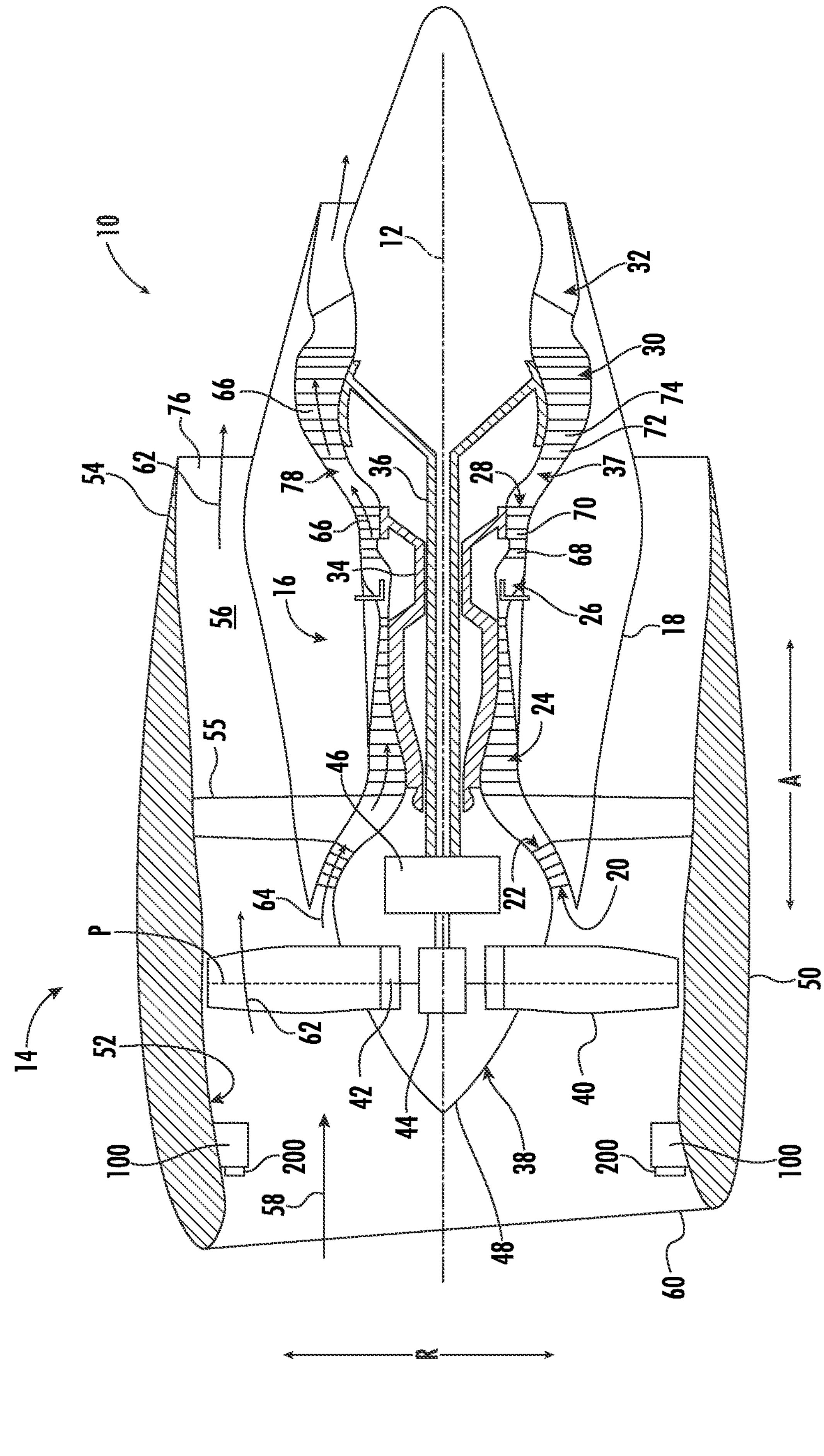
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56
18
55
24
46
A
22
20
64
P
62
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40
50
14
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44
38
100
200
200
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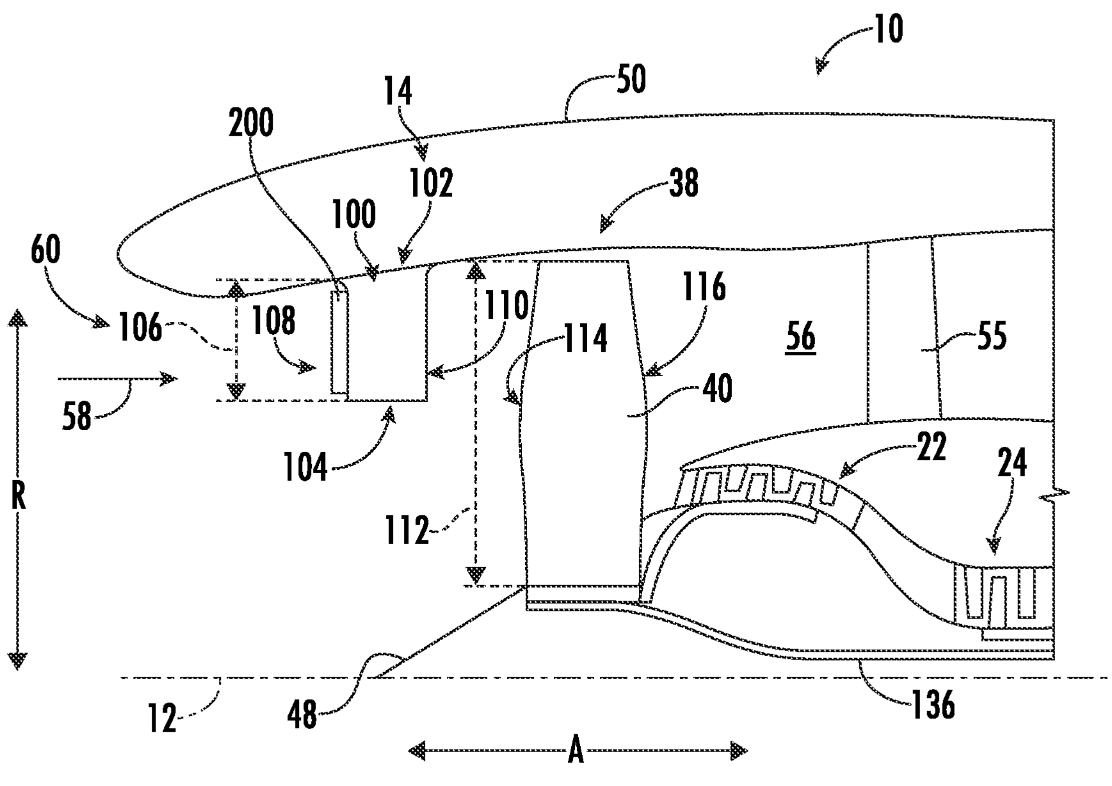
58
48
60
R

FIG. 1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112
12
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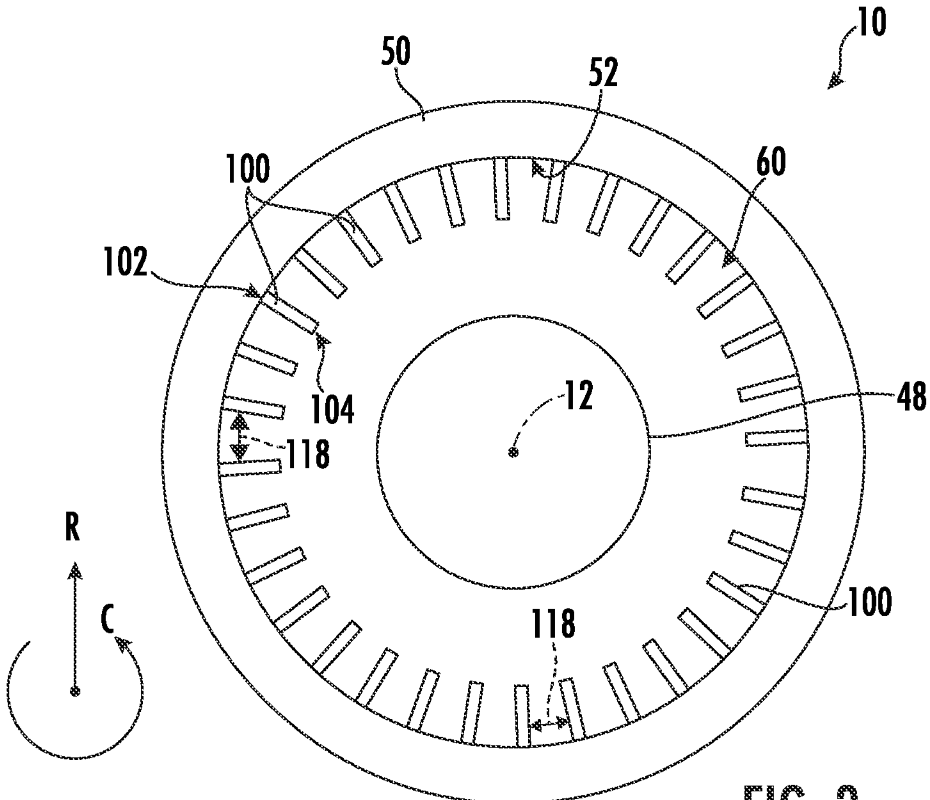
136
A

FIG. 2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52
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118
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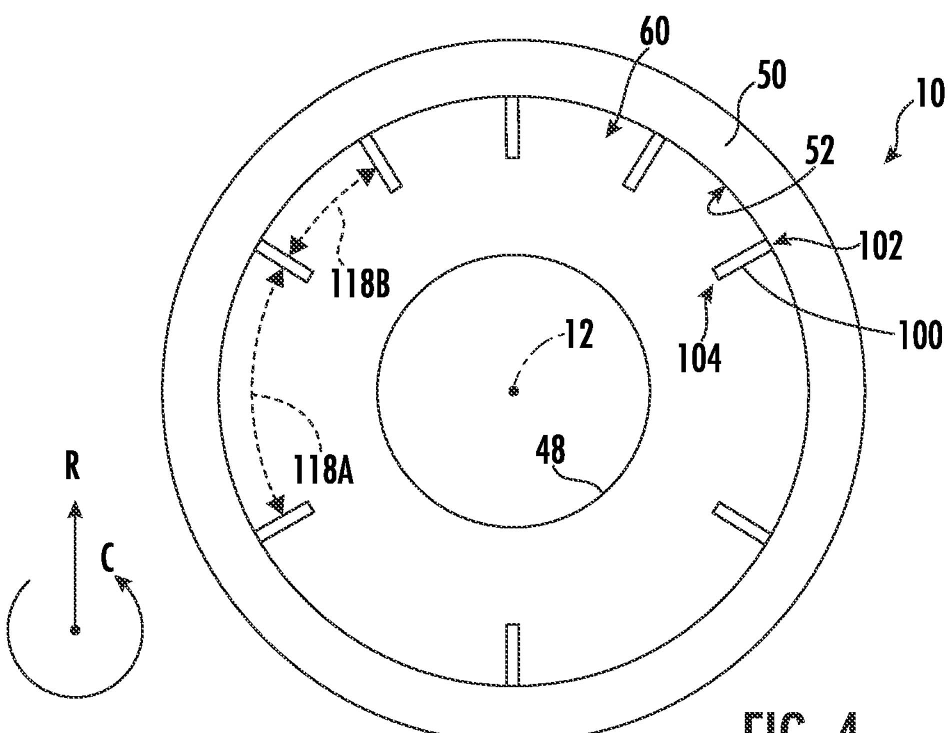
C
100
118

FIG. 3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118A
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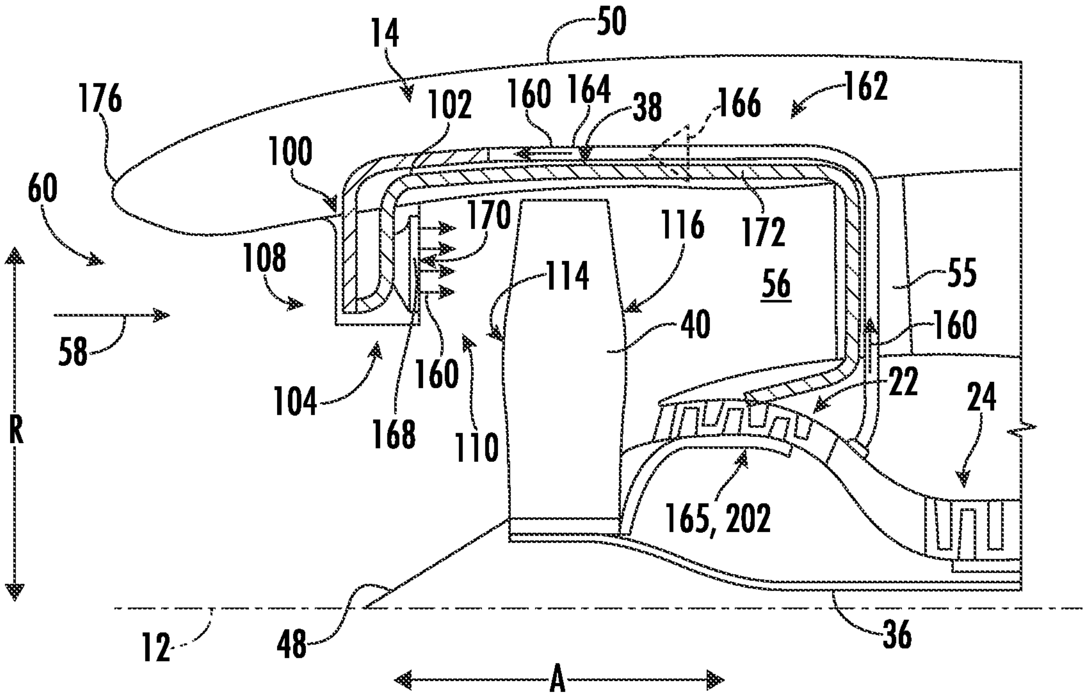
FIG. 4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166
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116
172
108
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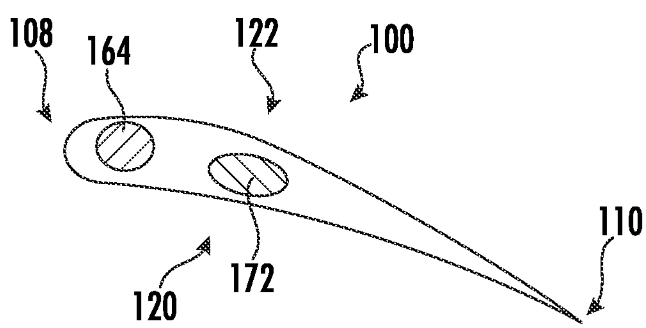
104
160
22
24
R
168
110
165, 202
12
48
36
A

FIG. 5A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172
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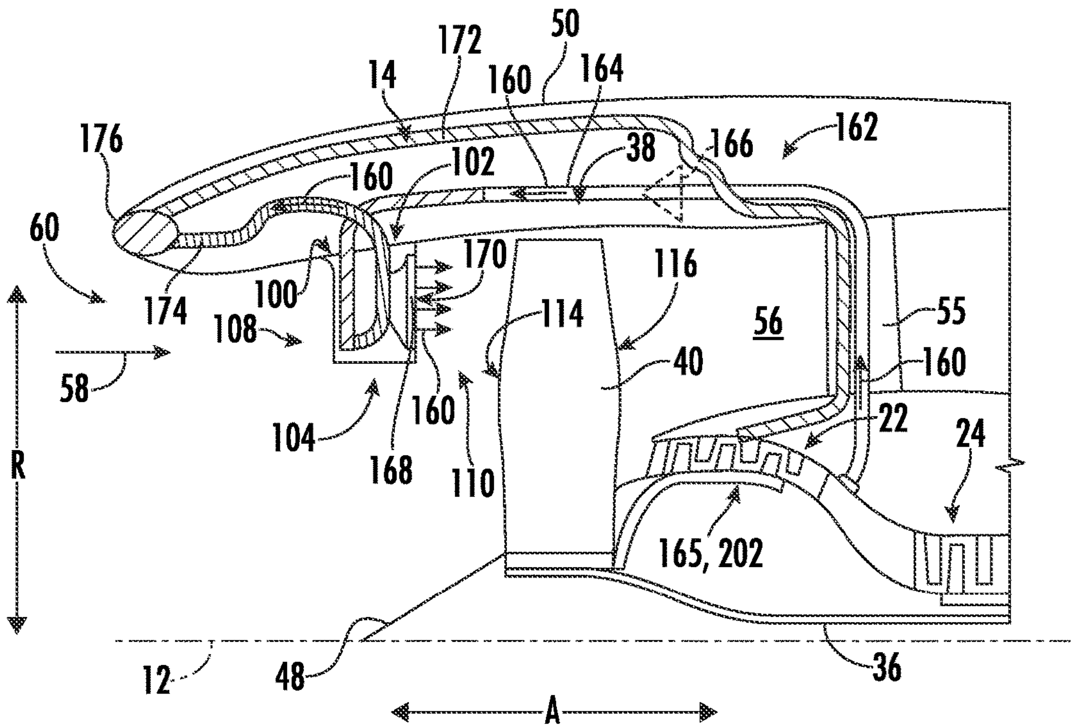
FIG. 5B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160
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160
22
168
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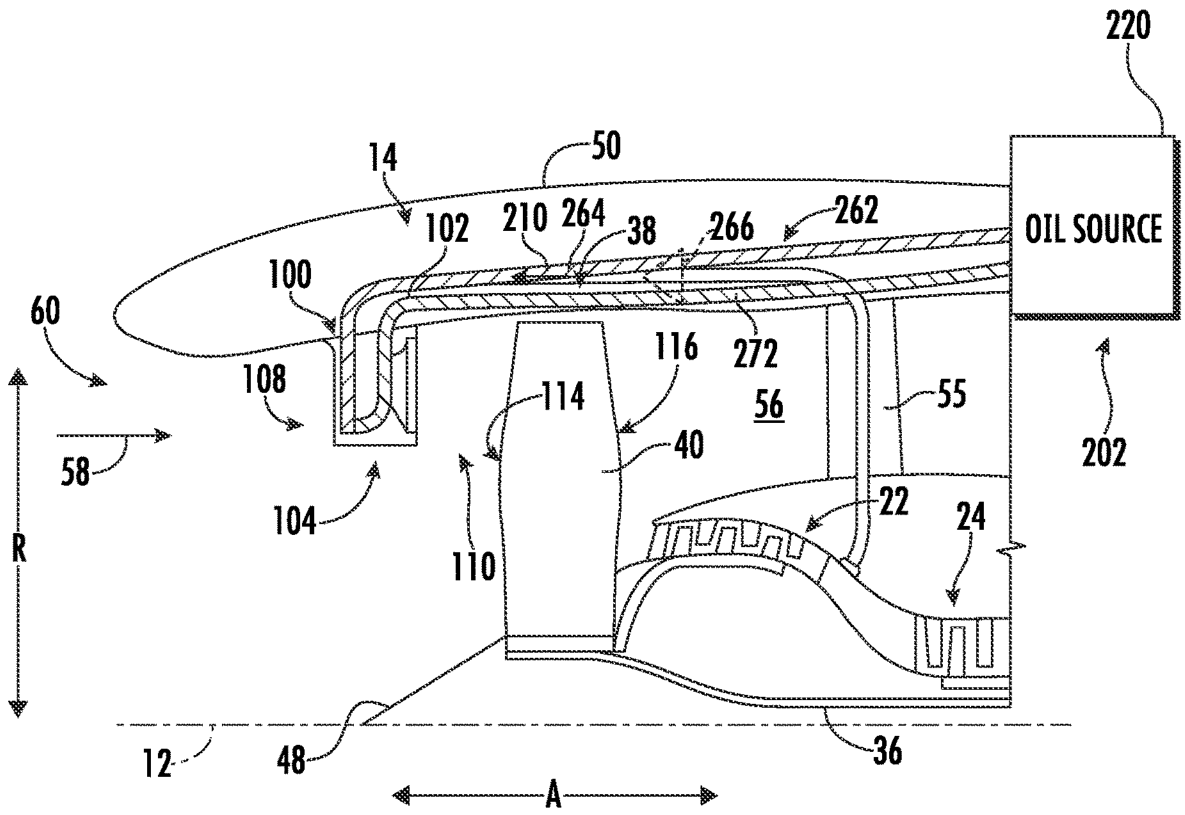
24
R
165, 202
12
48
36
A

FIG. 6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22
110
24
R
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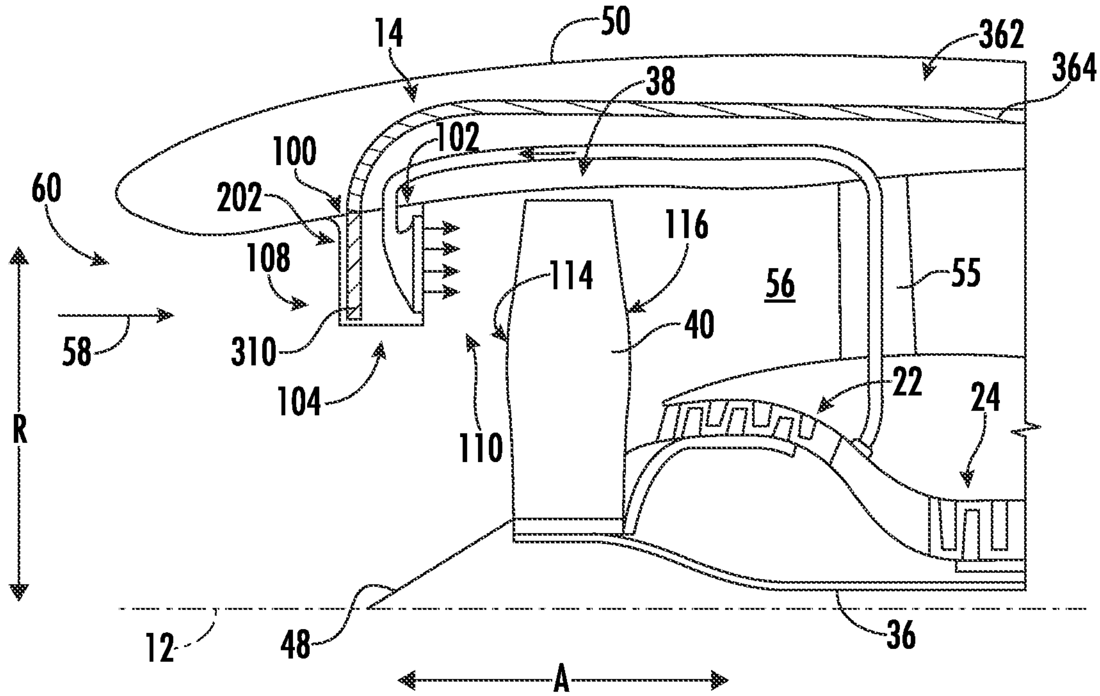
48
36
A

FIG. 7



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310
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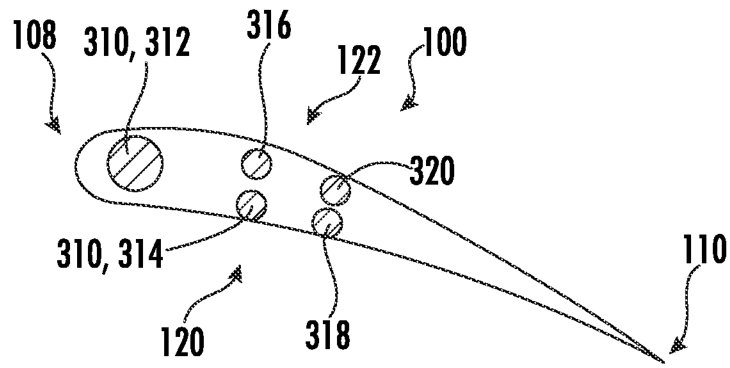
R
110
12
48
36
A


FIG. 8A



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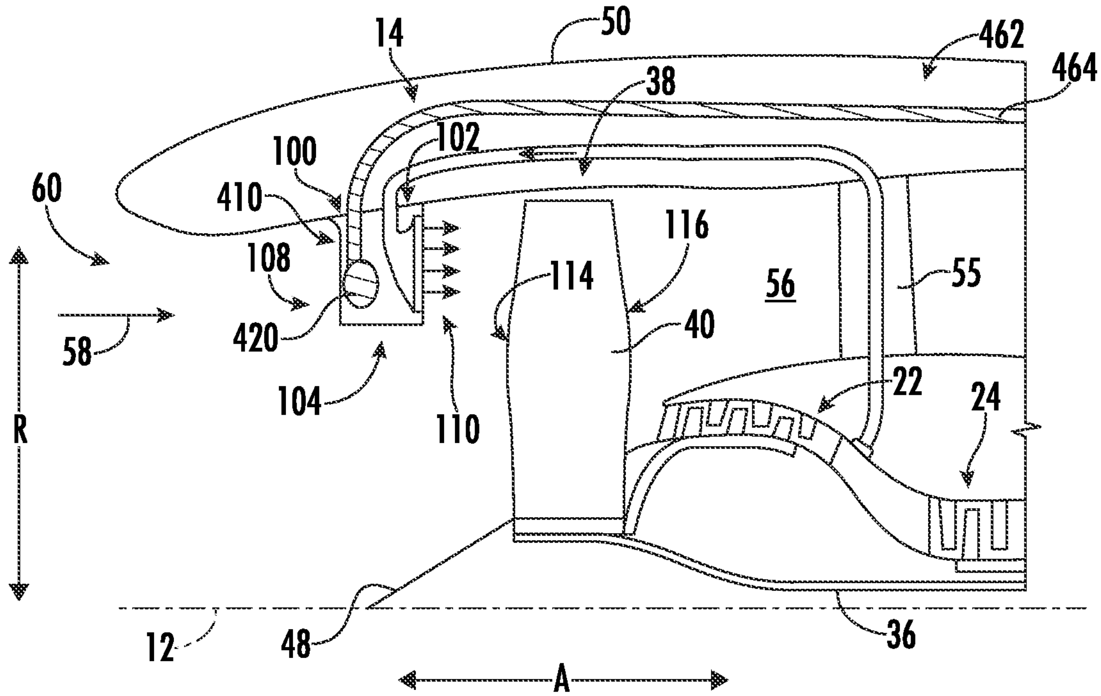
310, 314
110
120
318


FIG. 8B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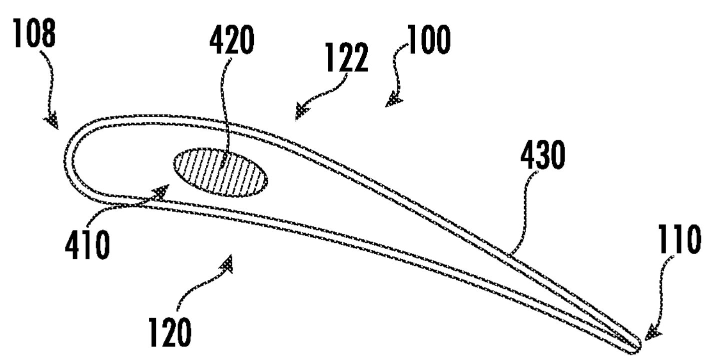
12
48
36
A

FIG. 9A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420
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430
410
110
120

FIG. 9B

# ICE REDUCTION MECHANISM FOR TURBOFAN ENGINE

## TECHNICAL FIELD

The present subject matter relates generally to a gas turbine engine, or more particularly to a gas turbine engine configured to reduce ice buildup or ice formation on inlet components of the engine.

## BACKGROUND

A turbofan engine generally includes a fan having a plurality of fan blades and a turbomachine arranged in flow communication with one another. Additionally, the turbomachine of the turbofan engine generally includes, in serial flow order, a compressor section, a combustion section, a turbine section, and an exhaust section. In operation, air is provided from the fan to an inlet of the compressor section where one or more axial compressors progressively compress the air until it reaches the combustion section. Fuel is mixed with the compressed air and burned within the combustion section to provide combustion gases. The combustion gases are routed from the combustion section to the turbine section. The flow of combustion gasses through the turbine section drives the turbine section and is then routed through the exhaust section, e.g., to atmosphere.

However, during inclement weather, freezing rain, hail, sleet, ice, etc., can accumulate on the inlet components of the turbofan engine. When ice accumulates, it can break off and be ingested into the engine. Further, large portions of ice can damage the fan blades or other downstream components of the engine, and may potentially cause an engine flameout.

## BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present disclosure, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

FIG. **1** is a schematic cross-sectional view of an exemplary gas turbine engine according to an exemplary embodiment of the present subject matter.

FIG. **2** is a close-up, schematic, cross-sectional view of a forward end of the exemplary gas turbine engine of FIG. **1** according to an exemplary embodiment of the present subject matter.

FIG. **3** is a schematic view of an inlet to the exemplary gas turbine engine of FIG. **1**, along an axial direction of the gas turbine engine of FIG. **1** according to an exemplary embodiment of the present subject matter.

FIG. **4** it is a schematic view of an inlet to a gas turbine engine in accordance with another exemplary embodiment of the present disclosure.

FIG. **5**A is a schematic cross-sectional view of an exemplary gas turbine engine according to an exemplary embodiment of the present subject matter.

FIG. **5**B is a cross-sectional view of a part span inlet guide vane of an exemplary gas turbine engine at a first location along a span of the part span inlet guide vane according to an exemplary embodiment of the present subject matter.

FIG. **6** is a schematic cross-sectional view of an exemplary gas turbine engine according to another exemplary embodiment of the present subject matter.

FIG. **7** is a schematic cross-sectional view of an exemplary gas turbine engine according to another exemplary embodiment of the present subject matter.

FIG. **8**A is a schematic cross-sectional view of an exemplary gas turbine engine according to another exemplary embodiment of the present subject matter.

FIG. **8**B is a cross-sectional view of a part span inlet guide vane of an exemplary gas turbine engine at a first location along a span of the part span inlet guide vane according to another exemplary embodiment of the present subject matter.

FIG. **9**A is a schematic cross-sectional view of an exemplary gas turbine engine according to another exemplary embodiment of the present subject matter.

FIG. **9**B is a cross-sectional view of a part span inlet guide vane of the exemplary gas turbine engine of FIG. **9**A at a first location along a span of the part span inlet guide vane according to another exemplary embodiment of the present subject matter.

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate exemplary embodiments of the disclosure, and such exemplifications are not to be construed as limiting the scope of the disclosure in any manner.

## DETAILED DESCRIPTION

Reference will now be made in detail to present embodiments of the disclosure, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the disclosure.

The following description is provided to enable those skilled in the art to make and use the described embodiments contemplated for carrying out the disclosure. Various modifications, equivalents, variations, and alternatives, however, will remain readily apparent to those skilled in the art. Any and all such modifications, variations, equivalents, and alternatives are intended to fall within the scope of the present disclosure.

The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any implementation described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other implementations. Additionally, unless specifically identified otherwise, all embodiments described herein should be considered exemplary.

For purposes of the description hereinafter, the terms "upper", "lower", "right", "left", "vertical", "horizontal", "top", "bottom", "lateral", "longitudinal", and derivatives thereof shall relate to the disclosure as it is oriented in the drawing figures. However, it is to be understood that the disclosure may assume various alternative variations, except where expressly specified to the contrary. It is also to be understood that the specific devices illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the disclosure. Hence, specific dimensions and other physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

As used herein, the terms "first", "second", and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components.

The terms "forward" and "aft" refer to relative positions within a gas turbine engine, with forward referring to a position closer to an engine inlet and aft referring to a position closer to an engine nozzle or exhaust.

The terms "upstream" and "downstream" refer to the relative direction with respect to fluid flow in a fluid pathway. For example, "upstream" refers to the direction from which the fluid flows, and "downstream" refers to the direction to which the fluid flows.

The singular forms "a", "an", and "the" include plural references unless the context clearly dictates otherwise.

Additionally, the terms "low," "high," or their respective comparative degrees (e.g., lower, higher, where applicable) each refer to relative speeds or pressures within an engine, unless otherwise specified. For example, a "low-pressure turbine" operates at a pressure generally lower than a "high-pressure turbine." Alternatively, unless otherwise specified, the aforementioned terms may be understood in their superlative degree. For example, a "low-pressure turbine" may refer to the lowest maximum pressure turbine within a turbine section, and a "high-pressure turbine" may refer to the highest maximum pressure turbine within the turbine section. An engine of the present disclosure may also include an intermediate pressure turbine, e.g., an engine having three spools.

Approximating language, as used herein throughout the specification and claims, is applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about", "approximately", and "substantially", are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or machines for constructing or manufacturing the components and/or systems. For example, the approximating language may refer to being within a 1, 2, 4, 10, 15, or 20 percent margin. These approximating margins may apply to a single value, either or both endpoints defining numerical ranges, and/or the margin for ranges between endpoints.

Here and throughout the specification and claims, range limitations are combined and interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

As used herein, the term "fan pressure ratio" refers to a ratio of an air pressure immediately downstream of the fan blades if a fan during operation of the fan to an air pressure immediately upstream of the fan blades of the fan during operation of the fan.

As used herein, the term "rated speed" with reference to a turbofan engine refers to a maximum rotational speed that the turbofan engine may achieve while operating properly. For example, the turbofan engine may be operating at the rated speed during maximum load operations, such as during takeoff operations.

Also as used herein, the term "fan tip speed" as defined by the plurality of fan blades of the fan refers to a linear speed of an outer tip of a fan blade along a radial direction during operation of the fan.

The present disclosure is generally related to a means for reducing ice buildup or ice formation on inlet components of an engine, e.g., an inlet pre-swirl feature configured as a plurality of part span inlet guide vanes.

In some exemplary embodiments of the present disclosure, the means for reducing ice buildup or ice formation includes a heat source that is in thermal communication with the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes. For example, in a first exemplary embodiment, the heat source includes an engine bleed airflow. In another exemplary embodiment, the heat source includes an electrical heating element disposed in a leading edge of the inlet pre-swirl feature. In yet another exemplary embodiment, the heat source includes an engine oil.

In other exemplary embodiment, the means for reducing ice buildup or ice formation includes a vibration assembly in mechanical communication with the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes, or an anti-icing coating on the pre-swirl feature.

Inclusion of one or more of these means for reducing ice buildup or ice formation provides an anti-icing or de-icing mechanism that prevents the buildup and shedding of pieces of ice into the engine during, e.g., adverse weather conditions, resulting in safer operation of the gas turbine engine.

Referring now to the drawings, wherein identical numerals indicate the same elements throughout the figures, FIG. **1** is a schematic cross-sectional view of a gas turbine engine in accordance with an exemplary embodiment of the present disclosure. More particularly, for the embodiment of FIG. **1**, the gas turbine engine is an aeronautical, turbofan jet engine **10**, referred to herein as "turbofan engine **10**", configured to be mounted to an aircraft, such as in an under-wing configuration or tail-mounted configuration. As shown in FIG. **1**, the turbofan engine **10** defines an axial direction A (extending parallel to a longitudinal centerline **12** provided for reference), a radial direction R, and a circumferential direction (i.e., a direction extending about the axial direction A; not depicted). In general, the turbofan **10** includes a fan section **14** and a turbomachine **16** disposed downstream from the fan section **14** (the turbomachine **16** sometimes also, or alternatively, referred to as a "core turbine engine").

The exemplary turbomachine **16** depicted generally includes a substantially tubular outer casing **18** that defines an annular inlet **20**. The outer casing **18** encases, in serial flow relationship, a compressor section including a first, booster or low pressure (LP) compressor **22** and a second, high pressure (HP) compressor **24**; a combustion section **26**; a turbine section including a first, high pressure (HP) turbine **28** and a second, low pressure (LP) turbine **30**; and a jet exhaust nozzle section **32**. A high pressure (HP) shaft **34** drivingly connects the HP turbine **28** to the HP compressor **24**. A low pressure (LP) shaft **36** drivingly connects the LP turbine **30** to the LP compressor **22**. The compressor section, combustion section **26**, turbine section, and jet exhaust nozzle section **32** are arranged in serial flow order and together define a core air flowpath **37** through the turbomachine **16**. It is also contemplated that the present disclosure is compatible with an engine having an intermediate pressure turbine, e.g., an engine having three spools.

Referring still the embodiment of FIG. **1**, the fan section **14** includes a variable pitch, single stage fan **38**, the turbomachine **16** operably coupled to the fan **38** for driving the fan **38**. The fan **38** includes a plurality of rotatable fan blades **40** coupled to a disk **42** in a spaced apart manner. As depicted, the fan blades **40** extend outwardly from disk **42** generally along the radial direction R. Each fan blade **40** is rotatable relative to the disk **42** about a pitch axis P by virtue of the fan blades **40** being operatively coupled to a suitable actuation member **44** configured to collectively vary the pitch of the fan blades **40**, e.g., in unison. The fan blades **40**, disk **42**, and actuation member **44** are together rotatable about the longitudinal centerline **12** by LP shaft **36** across a power gear box **46**. The power gear box **46** includes a plurality of gears for stepping down the rotational speed of the LP shaft **36** to a more efficient rotational fan speed.

Accordingly, for the embodiment depicted, the turbomachine **16** is operably coupled to the fan **38** through the power gear box **46**.

In exemplary embodiments, the fan section **14** includes twenty-two (22) or fewer fan blades **40**. In certain exemplary embodiments, the fan section **14** includes twenty (20) or fewer fan blades **40**. In certain exemplary embodiments, the fan section **14** includes eighteen (18) or fewer fan blades **40**. In certain exemplary embodiments, the fan section **14** includes sixteen (16) or fewer fan blades **40**. In certain exemplary embodiments, it is contemplated that the fan section **14** includes other number of fan blades **40** for a particular application.

During operation of the turbofan engine **10**, the fan **38** defines a fan pressure ratio and the plurality of fan blades **40** each define a fan tip speed. The exemplary turbofan engine **10** depicted defines a relatively high fan tip speed and relatively low fan pressure ratio during operation of the turbofan engine at a rated speed. As used herein, the term "fan pressure ratio" refers to a ratio of an air pressure immediately downstream of the fan blades **40** during operation of the fan **38** to an air pressure immediately upstream of the fan blades **40** during operation of the fan **38**. For the embodiment depicted in FIG. **1**, the fan **38** of the turbofan engine **10** defines a relatively low fan pressure ratio. For example, the turbofan engine **10** depicted defines a fan pressure ratio less than or equal to about 1.5. For example, in certain exemplary embodiments, the turbofan engine **10** may define a fan pressure ratio less than or equal to about 1.4. The fan pressure ratio may be the fan pressure ratio of the fan **38** during operation of the turbofan engine **10**, such as during operation of the turbofan engine **10** at a rated speed.

As used herein, the term "rated speed" with reference to the turbofan engine **10** refers to a maximum rotational speed that the turbofan engine **10** may achieve while operating properly. For example, the turbofan engine **10** may be operating at the rated speed during maximum load operations, such as during takeoff operations.

Also as used herein, the term "fan tip speed" defined by the plurality of fan blades **40** refers to a linear speed of an outer tip of a fan blade **40** along the radial direction R during operation of the fan **38**. In exemplary embodiments, the turbofan engine **10** of the present disclosure causes the fan blades **40** of the fan **38** to rotate at a relatively high rotational speed. For example, during operation of the turbofan engine **10** at the rated speed, the fan tip speed of each of the plurality of fan blades **40** is greater than or equal to 1000 feet per second and less than or equal to 2250 feet per second. In certain exemplary embodiments, during operation of the turbofan engine **10** at the rated speed, the fan tip speed of each of the fan blades **40** may be greater than or equal to 1,250 feet per second and less than or equal to 2250 feet per second. In certain exemplary embodiments, during operation of the turbofan engine **10** at the rated speed, the fan tip speed of each of the fan blades **40** may be greater than or equal to about 1,350 feet per second, such as greater than about 1,450 feet per second, such as greater than about 1,550 feet per second, and less than or equal to 2250 feet per second.

Referring still to the exemplary embodiment of FIG. **1**, the disk **42** is covered by rotatable front nacelle or hub **48** aerodynamically contoured to promote an airflow through the plurality of fan blades **40**. Additionally, the exemplary fan section **14** includes an annular fan casing or outer nacelle **50** that at least partially, and for the embodiment depicted, circumferentially, surrounds the fan **38** and at least a portion of the turbomachine **16**.

More specifically, the outer nacelle **50** includes an inner wall **52** and a downstream section **54** of the inner wall **52** of the outer nacelle **50** extends over an outer portion of the turbomachine **16** so as to define a bypass airflow passage **56** therebetween. Additionally, for the embodiment depicted, the outer nacelle **50** is supported relative to the turbomachine **16** by a plurality of circumferentially spaced outlet guide vanes **55**.

During operation of the turbofan engine **10**, a volume of air **58** enters the turbofan engine **10** through an associated inlet **60** of the outer nacelle **50** and/or fan section **14**. As the volume of air **58** passes across the fan blades **40**, a first portion of the air **58** as indicated by arrows **62** is directed or routed into the bypass airflow passage **56** and a second portion of the air **58** as indicated by arrow **64** is directed or routed into the core air flowpath **37**. The ratio between an amount of airflow through the bypass airflow passage **56** (i.e., the first portion of air indicated by arrows **62**) to an amount of airflow through the core air flowpath **37** (i.e., the second portion of air indicated by arrows **64**) is known as a bypass ratio.

In exemplary embodiments, the bypass ratio during operation of the turbofan engine **10** (e.g., at a rated speed) is less than or equal to about eleven (11). For example, the bypass ratio during operation of the turbofan engine **10** (e.g., at a rated speed) may be less than or equal to about ten (10), such as less than or equal to about nine (9). Additionally, the bypass ratio may be at least about two (2).

In other exemplary embodiments, the bypass ratio may generally be between about 7:1 and about 20:1, such as between about 10:1 and about 18:1. The pressure of the second portion of air indicated by arrows **64** is then increased as it is routed through the high pressure (HP) compressor **24** and into the combustion section **26**, where it is mixed with fuel and burned to provide combustion gases **66**.

In exemplary embodiments, a gear ratio of the power gear box **46** is greater than or equal to 1.2 and less than or equal to 3.0. In some exemplary embodiments, the gear ratio of the power gear box **46** is greater than or equal to 1.2 and less than or equal to 2.6. In other exemplary embodiments, the gear ratio of the power gear box **46** is greater than or equal to 1.2 and less than or equal to 2.0.

Furthermore, the turbofan engine of the present disclosure also provides pre-swirling flow forward of the fan blade tip as described herein.

Referring still to FIG. **1**, the compressed second portion of air indicated by arrows **64** from the compressor section mixes with fuel and is burned within the combustion section to provide combustion gases **66**. The combustion gases **66** are routed from the combustion section **26**, through the HP turbine **28** where a portion of thermal and/or kinetic energy from the combustion gases **66** is extracted via sequential stages of HP turbine stator vanes **68** that are coupled to the outer casing **18** and HP turbine rotor blades **70** that are coupled to the HP shaft **34**, thus causing the HP shaft **34** to rotate, thereby supporting operation of the HP compressor **24**. The combustion gases **66** are then routed through the LP turbine **30** where a second portion of thermal and kinetic energy is extracted from the combustion gases **66** via sequential stages of LP turbine stator vanes **72** that are coupled to the outer casing **18** and LP turbine rotor blades **74** that are coupled to the LP shaft **36**, thus causing the LP shaft **36** to rotate, thereby supporting operation of the LP compressor **22** and/or rotation of the fan **38**.

The combustion gases **66** are subsequently routed through the jet exhaust nozzle section **32** of the turbomachine **16** to provide propulsive thrust. Simultaneously, the pressure of the first portion of air indicated by arrows **62** is substantially increased as the first portion of air **62** is routed through the bypass airflow passage **56** before it is exhausted from a fan nozzle exhaust section **76** of the turbofan **10**, also providing propulsive thrust. The HP turbine **28**, the LP turbine **30**, and the jet exhaust nozzle section **32** at least partially define a hot gas path **78** for routing the combustion gases **66** through the turbomachine **16**.

Referring still to FIG. **1**, the turbofan engine **10** additionally includes a means for reducing ice buildup or ice formation **200** on an inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, as described in greater detail herein.

In some exemplary embodiments, it will be appreciated that the exemplary turbofan engine **10** of the present disclosure may be a relatively large power class turbofan engine **10**. Accordingly, when operated at the rated speed, the turbofan engine **10** may be configured to generate a relatively large amount of thrust. More specifically, when operated at the rated speed, the turbofan engine **10** may be configured to generate at least about 20,000 pounds of thrust, such as at least about 25,000 pounds of thrust, such as at least about 30,000 pounds of thrust, and up to, e.g., about 150,000 pounds of thrust. Accordingly, the turbofan engine **10** may be referred to as a relatively large power class gas turbine engine.

Moreover, it should be appreciated that the exemplary turbofan engine **10** depicted in FIG. **1** is by way of example only, and that in other exemplary embodiments, the turbofan engine **10** may have any other suitable configuration. For example, in certain exemplary embodiments, the fan may not be a variable pitch fan, the engine may not include a reduction gearbox (e.g., power gearbox **46**) driving the fan, may include any other suitable number or arrangement of shafts, spools, compressors, turbines, etc.

As discussed above, the turbofan engine **10** of the present disclosure also provides pre-swirling flow forward a tip of the fan blade **40**. Referring now also to FIG. **2**, a close-up, cross-sectional view of the fan section **14** and forward end of the turbomachine **16** of the exemplary turbofan engine **10** of FIG. **1** is provided. In exemplary embodiments, the turbofan engine **10** includes an inlet pre-swirl feature located upstream of the plurality of fan blades **40** of the fan **38** and attached to or integrated into the outer nacelle **50**. More specifically, for the embodiment of FIGS. **1** and **2**, the inlet pre-swirl feature is configured as a plurality of part span inlet guide vanes **100**. The plurality of part span inlet guide vanes **100** are each cantilevered from of the outer nacelle **50** (such as from the inner wall **52** of the outer nacelle **50**) at a location forward of the plurality of fan blades **40** of the fan **38** along the axial direction A and aft of the inlet **60** of the outer nacelle **50**. More specifically, each of the plurality of part span inlet guide vanes **100** define an outer end **102** along the radial direction R, and are attached to/connected to the outer nacelle **50** at the radially outer end **102** through a suitable connection means (not shown). For example, each of the plurality of part span inlet guide vanes **100** may be bolted to the inner wall **52** of the outer nacelle **50** at the outer end **102**, welded to the inner wall **52** of the outer nacelle **50** at the outer end **102**, or attached to the outer nacelle **50** in any other suitable manner at the outer end **102**.



Further, for the embodiment depicted, the plurality of part span inlet guide vanes **100** extend generally along the radial direction R from the outer end **102** to an inner end **104** (i.e., an inner end **104** along the radial direction R). Moreover, as will be appreciated, for the embodiment depicted, each of the plurality of part span inlet guide vanes **100** are unconnected with an adjacent part span inlet guide vane **100** at the respective inner ends **104** (i.e., adjacent part span inlet guide vanes **100** do not contact one another at the radially inner ends **104**, and do not include any intermediate connection members at the radially inner ends **104**, such as a connection ring, strut, etc.). More specifically, for the embodiment depicted, each part span inlet guide vane **100** is completely supported by a connection to the outer nacelle **50** at the respective outer end **102** (and not through any structure extending, e.g., between adjacent part span inlet guide vanes **100** at a location inward of the outer end **102** along the radial direction R). As will be discussed below, such may reduce an amount of turbulence generated by the part span inlet guide vanes **100**.

Moreover, is depicted, each of the plurality of part span inlet guide vanes **100** do not extend completely between the outer nacelle **50** and, e.g., the hub **48** of the turbofan engine **10**. More specifically, for the embodiment depicted, each of the plurality of inlet guide vane define an inlet guide vane ("IGV") span **106** along the radial direction R, and further each of the plurality of part span inlet guide vanes **100** further define a leading edge **108** and a trailing edge **110**. The IGV span **106** refers to a measure along the radial direction R between the outer end **102** and the inner end **104** of the part span inlet guide vane **100** at the leading edge **108** of the part span inlet guide vane **100**. Similarly, it will be appreciated, that the plurality of fan blades **40** of the fan **38** define a fan blade span **112** along the radial direction R. More specifically, each of the plurality of fan blades **40** of the fan **38** also defines a leading edge **114** and a trailing edge **116**, and the fan blade span **112** refers to a measure along the radial direction R between a radially outer tip and a base of the fan blade **40** at the leading edge **114** of the respective fan blade **40**.

For the embodiment depicted, the IGV span **106** is at least about five percent of the fan blade span **112** and up to about fifty-five percent of the fan blade span **112**. For example, in certain exemplary embodiments, the IGV span **106** may be between about fifteen percent of the fan blade span **112** and about forty-five percent of the fan blade span **112**, such as between about thirty percent of the fan blade span **112** and about forty percent of the fan blade span **112**.

Reference will now also be made to FIG. **3**, providing an axial view of the inlet **60** to the turbofan engine **10** of FIGS. **1** and **2**. As will be appreciated, for the embodiment depicted, the plurality of part span inlet guide vanes **100** of the turbofan engine **10** includes a relatively large number of part span inlet guide vanes **100**. More specifically, for the embodiment depicted, the plurality of part span inlet guide vanes **100** includes between about ten part span inlet guide vanes **100** and about fifty part span inlet guide vanes **100**. More specifically, for the embodiment depicted, the plurality of part span inlet guide vanes **100** includes between about twenty part span inlet guide vanes **100** and about forty-five part span inlet guide vanes **100**, and more specifically, still, the embodiment depicted includes thirty-two part span inlet guide vanes **100**. Additionally, for the embodiment depicted, each of the plurality of part span inlet guide vanes **100** are spaced substantially evenly along the circumferential direction C. More specifically, each of the plurality of part span inlet guide vanes **100** defines a circumferential spacing **118** with an adjacent part span inlet guide vane **100**, with the circumferential spacing **118** being substantially equal between each adjacent part span inlet guide vane **100**.

Although not depicted, in certain exemplary embodiments, the number of part span inlet guide vanes **100** may be substantially equal to the number of fan blades **40** of the fan **38** of the turbofan engine **10**. In other embodiments, however, the number of part span inlet guide vanes **100** may be greater than the number of fan blades **40** of the fan **38** of the turbofan engine **10**, or alternatively, may be less than the number of fan blades **40** of the fan **38** of the turbofan engine **10**.

Further, it should be appreciated, that in other exemplary embodiments, the turbofan engine **10** may include any other suitable number of part span inlet guide vanes **100** and/or circumferential spacing **118** of the part span inlet guide vanes **100**. For example, referring now briefly to FIG. **4**, an axial view of an inlet **60** to a turbofan engine **10** in accordance with another exemplary embodiment of the present disclosure is provided. For the embodiment of FIG. **4**, the turbofan engine **10** includes less than twenty part span inlet guide vanes **100**. More specifically, for the embodiment of FIG. **4**, the turbofan engine **10** includes at least eight part span inlet guide vanes **100**, or more specifically includes exactly eight part span inlet guide vanes **100**. Additionally, for the embodiment of FIG. **4**, the plurality of part span inlet guide vanes **100** are not substantially evenly spaced along the circumferential direction C. For example, at least certain of the plurality of part span inlet guide vanes **100** define a first circumferential spacing **118**A, while other of the plurality of part span inlet guide vanes **100** define a second circumferential spacing **118**B. For the embodiment depicted, the first circumferential spacing **118**A is at least about twenty percent greater than the second circumferential spacing **118**B, such as at least about twenty-five percent greater such as at least about thirty percent greater, such as up to about two hundred percent greater. Notably, as will be described in greater detail below, the circumferential spacing **118** refers to a mean circumferential spacing between adjacent part span inlet guide vanes **100**. The non-uniform circumferential spacing may, e.g., offset structure upstream of the part span inlet guide vanes **100**.

Referring back to FIG. **2**, it will be appreciated that each of the plurality of part span inlet guide vanes **100** is configured to pre-swirl an airflow **58** provided through the inlet **60** of the nacelle **50**, upstream of the plurality of fan blades **40** of the fan **38**. As briefly discussed above, pre-swirling the airflow **58** provided through the inlet **60** of the nacelle **50** prior to such airflow **58** reaching the plurality of fan blades **40** of the fan **38** may reduce separation losses and/or shock losses, allowing the fan **38** to operate with the relatively high fan tip speeds described above with less losses in efficiency.

As discussed, the present disclosure provides a means for reducing ice buildup or ice formation **200** on the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, in communication with the inlet pre-swirl feature. This provides an anti-icing or de-icing mechanism that prevents the buildup and shedding of pieces of ice into the engine during adverse weather conditions.

Referring now generally to FIGS. **5**A through **8**B, in exemplary embodiments of the present disclosure, the means for reducing ice buildup or ice formation **200** includes a heat source **202** that is in thermal communication with the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

Referring to FIG. **5**A, a close-up, cross-sectional view of a fan section **14** and a forward end of a turbomachine **16** of a turbofan engine **10** in accordance with an exemplary embodiment of the present disclosure is provided. The exemplary engine **10** of FIG. **5**A may be configured in a similar manner as the exemplary engine of FIG. **2** described above.

In the exemplary embodiment depicted, the heat source **202** includes an engine bleed airflow **160**. For example, in a first exemplary embodiment, referring to FIG. **5**A, the heat source **202** includes a bleed air supply assembly **162** including a bleed air supply duct **164** in airflow communication with a high pressure air source **165**, e.g., engine bleed airflow **160** from the engine **10**, and the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**. The bleed air supply duct **164** is configured to receive and provide the engine bleed airflow **160** to the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**. For example, the bleed air supply duct **164** may provide the engine bleed airflow **160** to a location proximate the leading edge **108**, e.g., to a location closer to the leading edge **108** than the trailing edge **110**.

In exemplary embodiments, the high pressure air source **165** is the compressor section, e.g., the LP compressor **22**, of the turbomachine **16**. For example, in an exemplary embodiment, hot compressor discharge air, e.g., the engine bleed airflow **160**, is routed to the leading edge **108** of the part span inlet guide vane **100** and then a cooler engine bleed airflow **160** is returned back to the turbomachine **16**. It is contemplated that the compressor discharge air may be sourced from any stage of the LP compressor **22** or the HP compressor **24**.

In this manner, the engine bleed airflow **160** is utilized to heat the part span inlet guide vane **100** and operate as a means for reducing ice buildup or ice formation at the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

In an exemplary embodiment, the bleed air supply assembly **162** further includes a bleed air return duct **172** in airflow communication with the bleed air supply duct **164** and a portion of the turbomachine **16**. For example, the bleed air return duct **172** is configured to return the engine bleed airflow **160** back to the turbomachine **16**, e.g., the LP compressor **22**. The return engine bleed airflow **160** may be injected back to the turbomachine **16** at any applicable stage of the turbofan engine **10** (e.g., upstream from where the bleed air supply duct **164** received the engine bleed airflow **160**) or dumped into the bypass airflow passage **56** as described herein.

In some exemplary embodiments, such as the exemplary embodiment of FIG. **5**A, the bleed air supply assembly **162** further includes a cavity **168** of the part span inlet guide vane **100** in communication with a portion of the engine bleed airflow **160**. Furthermore, the part span inlet guide vane **100** for the embodiment depicted further defines a trailing edge opening **170**, which is in airflow communication with the cavity **168**, and thus is in airflow communication with a portion of the bleed air supply assembly **162**. Accordingly, with such a configuration, a portion of the engine bleed airflow **160** may be provided from the bleed air supply assembly **162** to the cavity **168** of the part span inlet guide vane **100**, and further through the trailing edge opening **170** of the part span inlet guide vane **100** during operation of the turbofan engine **10** to reduce a wake formed by the respective part span inlet guide vane **100**.

In an exemplary embodiment, the bleed air supply assembly **162** further includes a valve **166** (depicted in phantom in FIG. **5**A) in communication with the bleed air supply duct **164**. The valve **166** is transitionable between an open position in which the bleed air supply duct **164** receives and provides the engine bleed airflow **160** to the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, and a closed position in which the bleed air supply duct **164** is not in airflow communication with the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

Referring now to FIG. **5**B, providing a cross-sectional view of a part span inlet guide vane **100** in accordance with an exemplary embodiment of the present disclosure, the locations of the bleed air supply duct **164** and the bleed air return duct **172** within the part span inlet guide vane **100** are shown. The exemplary part span inlet guide vane **100** of FIG. **5**B may be configured in a similar manner, as the exemplary part span inlet guide vane **100** of FIG. **5**A. However, for the embodiment of FIG. **5**B, the exemplary part span inlet guide vane **100** does not include a cavity **168** or a trailing edge opening **170**.

For example, the bleed air supply duct **164** is configured to receive and provide the engine bleed airflow **160** to the leading edge **108** of the part span inlet guide vane **100**. As shown, the bleed air return duct **172** is positioned between the bleed air supply duct **164** and the trailing edge **110** of the part span inlet guide vane **100**. Referring to FIG. **5**B, the part span inlet guide vane **100** includes the leading edge **108**, the trailing edge **110**, a pressure side **120**, and a suction side **122**.

Referring now to FIG. **6**, a close-up, cross-sectional view of a fan section **14** and a forward end of a turbomachine **16** of a turbofan engine **10** in accordance with an exemplary embodiment of the present disclosure is provided. The exemplary engine **10** of FIG. **6** may be configured in a similar manner as the exemplary engine of FIG. **5**A described above. In the exemplary embodiment of FIG. **6**, the bleed air supply assembly **162** further includes a bleed air intermediate duct **174** in airflow communication with and disposed between the bleed air supply duct **164** and the bleed air return duct **172**. The bleed air intermediate duct **174** is in airflow communication with an upstream end **176** of the outer nacelle **50** and is configured to receive and provide the engine bleed airflow **160** to the upstream end **176** of the outer nacelle **50**. In such an embodiment, the engine bleed airflow **160** through the bleed air supply duct **164** is the hottest portion of the engine bleed airflow **160**, the engine bleed airflow **160** through the bleed air intermediate duct **174** is a warm air, and the engine bleed airflow **160** through the bleed air return duct **172** is a cooler air return back to the turbomachine **16**, e.g., the LP compressor **22**. It is also contemplated that in other exemplary embodiments, the engine bleed airflow **160** could first be directed to the upstream end **176** of the outer nacelle **50** and then to the leading edge **108** of the part span inlet guide vane **100**. It is further contemplated that in other exemplary embodiments, the engine bleed airflow **160** could be simultaneously directed to the upstream end **176** of the outer nacelle **50** and the leading edge **108** of the part span inlet guide vane **100**.

In this manner, the engine bleed airflow **160** is utilized to heat the part span inlet guide vane **100** and the upstream end **176** of the outer nacelle **50**. As such, the engine bleed airflow **160** is utilized as a means for reducing ice buildup or ice formation at the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, and at the upstream end **176** of the outer nacelle **50**.

Referring now to FIG. **7**, a close-up, cross-sectional view of a fan section **14** and a forward end of a turbomachine **16** of a turbofan engine **10** in accordance with an exemplary embodiment of the present disclosure is provided. The exemplary engine **10** of FIG. **7** may be configured in a similar manner as the exemplary engine of FIG. **5**A described above. In the exemplary embodiment of the present disclosure depicted, the heat source **202** includes an engine oil flow or engine oil **210**. For example, in another exemplary embodiment, referring to FIG. **7**, the heat source **202** includes an oil supply assembly **262** including an oil supply duct **264** in flow communication with an oil source **220** of the turbofan engine **10** and the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**. The oil supply duct **264** is configured to receive and provide the engine oil **210** to the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

In this manner, the hot engine oil flow **210** is utilized to heat the part span inlet guide vane **100** and operate as a means for reducing ice buildup or ice formation at the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

In an exemplary embodiment, the oil supply assembly **262** further includes an oil return duct **272** in flow communication with the oil supply duct **264** and the oil source **220**. For example, the oil return duct **272** is configured to return the engine oil **210** back to the oil source **220**.

In an exemplary embodiment, the oil supply assembly **262** may further include a valve **266** (depicted in phantom) in communication with the oil supply duct **264**. The valve **266** is transitionable between an open position in which the oil supply duct **264** receives and provides the engine oil flow **210** to the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, and a closed position in which the oil supply duct **264** is not in airflow communication with the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

Referring now to FIG. **8**A, a close-up, cross-sectional view of a fan section **14** and a forward end of a turbomachine **16** of a turbofan engine **10** in accordance with an exemplary embodiment of the present disclosure is provided. The exemplary engine **10** of FIG. **8**A may be configured in a similar manner as the exemplary engine of FIG. **2** described above. In the exemplary embodiment depicted, the heat source **202** includes an electrical heating element **310** disposed proximate the leading edge **108** of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100** (e.g., closer to the leading edge **108** than the trailing edge **110**). For example, the heat source **202** is more specifically the electrical heating element **310** disposed in the leading edge **108** of the inlet pre-swirl feature.

In this manner, the electrical heating element **310** is utilized to heat the part span inlet guide vane **100** and operate as a means for reducing ice buildup or ice formation at the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

In an exemplary embodiment, the heat source **202** further includes an electrical supply assembly **362** including an electrical supply cable **364** of the turbofan engine **10** in electrical communication with the electrical heating element **310**.

Referring to FIG. **8**B, a cross-sectional view of a part span inlet guide vane **100**, the locations of an electrical heating element **310** within the part span inlet guide vane **100** are shown. For example, the electrical heating element **310** includes a first element **312** adjacent the leading edge **108**, e.g., the first element **312** is closer to the leading edge **108** than the trailing edge **110**, of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, and a second element **314** positioned aft of the first element **312** within the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**. It is contemplated that one or more electrical heating elements may be used to heat the part span inlet guide vane **100**. Referring to FIG. **8**B, the electrical heating element **310** may also include a third element **316**, a fourth element **318**, and a fifth element **320** each positioned aft of the first element **312** within the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

Referring to FIGS. **9**A and **9**B, in another exemplary embodiment of the present disclosure, the means for reducing ice buildup or ice formation **200** includes a vibration assembly **410** in mechanical communication with the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**.

In an exemplary embodiment, the vibration assembly **410** includes a piezoelectric transducer **420** that vibrates the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**. It is contemplated that the vibration assembly **410** may include any other vibration devices such as ultrasonic vibration devices. It is also contemplated that the vibration assembly **410** may be used with any of the heat source embodiments disclosed in FIGS. **5**A-**8**B.

In an exemplary embodiment, the vibration assembly **410** further includes an electrical supply assembly **462** including an electrical supply cable **464** of the turbofan engine **10** in electrical communication with the piezoelectric transducer **420**.

Referring to FIG. **9**B, a cross-sectional view of a part span inlet guide vane **100**, the location of the piezoelectric transducer **420** within the part span inlet guide vane **100** is shown. For example, the piezoelectric transducer **420** is positioned adjacent the leading edge **108** of the part span inlet guide vane **100**.

Furthermore, in another exemplary embodiment, the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, is covered with an anti-ice coating **430**. For example, in an exemplary embodiment, the anti-ice coating **430** may include an erosion coating or erosion layer that resists ice accumulation. In an exemplary embodiment, the erosion coating is polyurethane. In an exemplary embodiment, the anti-ice coating **430** has a shore hardness between Shore A50 and Shore D60. In another exemplary embodiment, the anti-ice coating **430** has a shore hardness of Shore A90.

It is contemplated that the anti-ice coating **430** may cover the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**, as shown in FIG. **9**B. However, it is also contemplated that the anti-ice coating **430** may only be applied to selected portions of the inlet pre-swirl feature, e.g., configured as a plurality of part span inlet guide vanes **100**. It is also contemplated that with a part span inlet guide vane **100** formed of a polymer composite airfoil with a metal leading edge **108**, the anti-ice coating **430** is applied only to portions aft of the metal leading edge **108**.

Further aspects of the disclosure are provided by the subject matter of the following clauses:

A turbofan engine comprising: a fan comprising a plurality of fan blades; a turbomachine operably coupled to the fan for driving the fan, the turbomachine comprising a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath; a nacelle surrounding and at least partially enclosing the fan; an inlet pre-swirl feature located upstream of the plurality of fan blades, the inlet pre-swirl feature attached to or integrated into the nacelle; and a means for reducing ice buildup or ice formation on the inlet pre-swirl feature, the means in communication with the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the means for reducing ice buildup or ice formation comprises a heat source in thermal communication with the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the heat source is in communication with a leading edge of the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the heat source comprises an engine bleed airflow.

The turbofan engine of any preceding clause, wherein the heat source includes an air supply assembly comprising a supply duct in airflow communication with a high pressure air source and a leading edge of the inlet pre-swirl feature, the supply duct configured to receive and provide the engine bleed airflow to the leading edge of the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the air supply assembly further comprises a return duct in airflow communication with the supply duct and a portion of the turbomachine, the return duct configured to return the engine bleed airflow back to the turbomachine.

The turbofan engine of any preceding clause, wherein the air supply assembly further comprises a valve in communication with the supply duct, the valve transitionable between an open position in which the supply duct receives and provides the engine bleed airflow to the leading edge of the inlet pre-swirl feature, and a closed position in which the supply duct is not in airflow communication with the leading edge of the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the air supply assembly further comprises an intermediate duct in airflow communication with and disposed between the supply duct and the return duct, the intermediate duct in airflow communication with an upstream end of the nacelle and configured to receive and provide the engine bleed airflow to the upstream end of the nacelle.

The turbofan engine of any preceding clause, wherein the high pressure air source is the compressor section of the turbomachine.

The turbofan engine of any preceding clause, wherein the heat source comprises an electrical heating element disposed in thermal communication with a leading edge of the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the electrical heating element comprises a first element adjacent the leading edge of the inlet pre-swirl feature and a second element positioned aft of the first element within the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the heat source includes an electrical supply assembly comprising an electrical supply cable in electrical communication with the electrical heating element.

The turbofan engine of any preceding clause, wherein the heat source comprises an engine oil.

The turbofan engine of any preceding clause, wherein the heat source includes an oil supply assembly comprising an oil supply duct in flow communication with an oil source and a leading edge of the inlet pre-swirl feature, the oil supply duct configured to receive and provide the engine oil to the leading edge of the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the oil supply assembly further comprises an oil return duct in flow communication with the oil supply duct and the oil source, the oil return duct configured to return the engine oil back to the oil source.

The turbofan engine of any preceding clause, wherein the oil supply assembly further comprises a valve in communication with the oil supply duct, the valve transitionable between an open position in which the oil supply duct receives and provides the engine oil to the leading edge of the inlet pre-swirl feature, and a closed position in which the oil supply duct is not in flow communication with the leading edge of the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the means for reducing ice buildup or ice formation comprises a vibration assembly in mechanical communication with the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the means for reducing ice buildup or ice formation on the inlet pre-swirl feature in communication with the inlet pre-swirl feature comprises a piezoelectric transducer that vibrates the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the means for reducing ice buildup or ice formation on the inlet pre-swirl feature in communication with the inlet pre-swirl feature comprises an anti-ice coating covering the inlet pre-swirl feature.

The turbofan engine of any preceding clause, wherein the inlet pre-swirl feature comprises a part span inlet guide vane at a location forward of the plurality of fan blades of the fan along an axial direction and aft of an inlet of the nacelle.

A turbofan engine comprising: a fan comprising a plurality of fan blades; a turbomachine operably coupled to the fan for driving the fan, the turbomachine comprising a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath; a nacelle surrounding and at least partially enclosing the fan; an inlet pre-swirl feature located upstream of the plurality of fan blades, the inlet pre-swirl feature attached to or integrated into the nacelle; and one or more of: a heat source in thermal communication with the inlet pre-swirl feature; a vibration assembly in mechanical communication with the inlet pre-swirl feature; a piezoelectric transducer that vibrates the inlet pre-swirl feature; and an anti-ice coating covering the inlet pre-swirl feature.

This written description uses examples to disclose the disclosure, including the best mode, and also to enable any person skilled in the art to practice the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

While this disclosure has been described as having exemplary designs, the present disclosure can be further modified within the scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the disclosure using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this disclosure pertains and which fall within the limits of the appended claims.

What is claimed is:

**1**. A turbofan engine comprising:

a fan comprising a plurality of fan blades;

a turbomachine operably coupled to the fan for driving the fan, the turbomachine comprising a compressor section, a combustion section, and a turbine section in serial flow order and together defining a core air flowpath;

a nacelle surrounding and at least partially enclosing the fan;

an inlet pre-swirl feature located upstream of the plurality of fan blades, the inlet pre-swirl feature attached to or integrated into the nacelle; and

a means for reducing ice buildup or ice formation on the inlet pre-swirl feature, the means in communication with the inlet pre-swirl feature, wherein the means for reducing ice buildup or ice formation comprises a heat source in thermal communication with the inlet pre-swirl feature, wherein the heat source comprises an engine bleed airflow,

wherein the heat source includes an air supply assembly comprising:

a supply duct in airflow communication with a high pressure air source and a leading edge of the inlet pre-swirl feature, the supply duct configured to receive and provide the engine bleed airflow to the leading edge of the inlet pre-swirl feature;

a return duct in airflow communication with the supply duct and a portion of the turbomachine; and

an intermediate duct in airflow communication with and disposed between the supply duct and the return duct, the intermediate duct in airflow communication with an upstream end of the nacelle and configured to receive and provide the engine bleed airflow to the upstream end of the nacelle.

**2**. The turbofan engine of claim **1**, wherein the heat source is in communication with a leading edge of the inlet pre-swirl feature.

**3**. The turbofan engine of claim **1**, wherein the return duct is configured to return the engine bleed airflow back to the turbomachine.

**4**. The turbofan engine of claim **3**, wherein the air supply assembly further comprises a valve in communication with the supply duct, the valve transitionable between an open position in which the supply duct receives and provides the engine bleed airflow to the leading edge of the inlet pre-swirl feature, and a closed position in which the supply duct is not in airflow communication with the leading edge of the inlet pre-swirl feature.

**5**. The turbofan engine of claim **1**, wherein the high pressure air source is the compressor section of the turbomachine.

**6**. The turbofan engine of claim **1**, wherein the means for reducing ice buildup or ice formation on the inlet pre-swirl feature in communication with the inlet pre-swirl feature comprises an anti-ice coating covering the inlet pre-swirl feature.

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